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A Comparison of Sighted and Visually Impaired Children's Text Comprehension

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Abstract

Aim: Do children with visual impairments outperform their sighted cohorts in reading and auditory comprehension tasks?

Methods: We address this question by applying panel regression techniques on a comprehensive sample of 16 children with visual impairments from a Greek special school for students with visual impairments. **Results:** By comparing the reader comprehender profile for both children types, we find that the children with visual impairments perform better than their sighted counterparts. The better performance is supported both unconditionally and conditionally on idiosyncratic characteristics, such as age, text complexity, modality, sex and reading ability.

Conclusion: Decomposing the reader comprehender profile into a literal, global and local type of questions we find that the results are mainly driven by the superior performance of the children with VI in the literal questions.

Keywords: Braille, Visual Impairment, Inference Making Ability, Reading Comprehension, Listening Comprehension

Word Count: 7997

What this paper adds?

There has been a strand of literature that has explored inference making, a core component of skilled comprehension, involved in print reading of sighted participants. However, limited research has been focused on children with visual impairments (VI), who are Braille readers, based on the assumption that they will be parallel to those in sighted children. The following study contributes to the literature by comparing the reading and listening comprehension of Greek children with VI and sighted children by using literal and inferential types of questions. Our analysis builds on random effects panel regression models, panel ordered logit models and bootstrapped t-tests which are novel in this context. Our results show that the children with VI outperform their sighted counterparts in literal questions, while no significant difference is observed for the global and local type of inferential questions. Their advantage is not compromised by the way the information is acquired, i.e., acoustically or tactilely.

1. Introduction

Numerous studies have explored certain aspects of text comprehension, namely literal and inferential comprehension, in print reading of sighted participants (e.g., Cain, Oakhill, & Bryant, 2004; Protopapas, Sideridis, Mouzaki, & Simos, 2007; Yuill, Oakhill, & Parkin, 1989). Similar research in children with VI, who are Braille readers, is more limited based on the comparable performance assumption (Edmonds & Pring, 2006).

Text comprehension is a multifaceted process that involves understanding information explicitly presented in the text and information that can be inferred from it (Kintsch & Kintsch, 2005). Inference making is a core component of skilled comprehension and is deficient in sighted children with good word reading but poor reading comprehension, namely a poor comprehender profile (Cain & Oakhill, 1999; Kendeou, van den Broek, White, & Lynch, 2009; Oakhill 1984; Oakhill & Cain, 2012; Nation, Clarke, Marshall, & Durand, 2004; Verhoeven & van Leeuwe, 2008). To develop a complete text comprehension it is necessary to attain a complete and coherent text representation in the reader's memory (Thurlow & van den Broek, 1997; Trabasso, Secco, & van den Broek, 1984; van den Broek, 1989), known as a mental model (Johnson-Laird, 1983) or a situation model (Kintsch, 1988). The reader's comprehension of the text material and the relations between this content constitute the reader's mental model. However, construction of this mental model in the reader's memory relies on information not explicitly mentioned in the text material. Consequently, readers are required to fill in missing details by generating *local* and *global* coherence inferences. Establishing connections between within-text materials caters for the former, while utilizing information from outside the text is required for the latter (Graesser, Singer, & Trabasso, 1994). Ultimately, both types of inferences are needed for fully understanding a text (Cain & Oakhill, 1999; Long & Chong, 2001).

Local and global coherence inferences can be stimulated through question asking, elaborating on textual concepts and coherence establishment (Kendeou, van den Broek, White, & Lynch, 2009). Local coherence inferences rely on extracting key information from constructs, such as pronouns and synonyms, then connecting the events together to construct a coherent memory representation (Graesser & Clark, 1985). Insufficient knowledge of word meanings and constructs would result in incoherent memory representation; hence impede complete text comprehension (Perfetti, Yang, & Schmalhofer, 2008). Global coherence inferences depend on the reader's ability to bring external information and knowledge to connect ideas presented in the text (Cain & Oakhill, 1999; 2014).

Skilled sighted adult readers make inferences to connect events or to fill in missing text details (Garnham & Oakhill, 1996; Graesser et al., 1994; van den Broek, 1994). In the case of sighted children, younger children are not as skilled in inference making compared to older children (e.g. Ackerman, 1986; Barnes, Dennis, & Haefele-Kalvaitis, 1996; Casteel, 1993; Casteel & Simpson, 1991; Lynch et al., 2008). Oakhill (1982; 1984) demonstrated the importance of literal and inferential comprehension in children's reading comprehension, showing that better comprehenders are better at inferring information within the text. Based on Cain and Oakhill (1999) and Bowyer-Crane and Snowling (2005) less-skilled comprehenders improved on text-connecting inferences upon reconsultation of the text, however no similar improvement was evident with regards to outside knowledge.

Sighted readers rely on their vision to access written information, while readers with VI, whose vision is absent or partially absent, rely on their tactile sense in order to attain information written in Braille. More specifically, in the Braille tactile writing system each character is arranged in a three by two (3×2) matrix by a combination of elevated dots. The Greek braille code includes 63 characters, seven of which are called diphthongs (i.e., combinations of two vowels) and occur as contractions (Argyropoulos & Papadimitriou, 2017). Characters do not carry accents in the Greek braille code, so the child with VI must know where the word is stressed when reading (Argyropoulos & Martos, 2006; Argyropoulos & Papadimitriou, 2015; Papadimitriou & Argyropoulos, 2017).

Comprehension performance has also been studied under different presentation modalities, namely reading and listening. When reading or listening to a text, meanings of words are retrieved and grouped into meaningful grammatical units and higher-level language skills such as comprehension monitoring and inference making are engaged to construct a unified and coherent mental model (Kendeou et al. 2014; Oakhill & Cain, 2012; Perfetti, Stafura, & Adlof, 2013). Listening comprehension has been considered to be essential for the acquisition of reading comprehension (Sticht & James, 1984) and has been part of theoretical models and assessments of reading (Hoover & Gough, 1990). Listening and reading comprehension are highly interrelated (Sticht, Beck, Hauke, Kleinman, & James, 1974) and change as a function of age (Curtis, 1980) with listening comprehension ability being higher than reading comprehension ability up to Grade 7 (Diakidoy et al., 2005); the opposite evidenced in adulthood (Sticht & James, 1984).

On the one hand, it has been observed that there is no performance difference with regards to reading or listening to a text *per se*, irrespective of comprehension skill (Cain, Oakhill, Barnes, & Bryant, 2001; Nation & Snowling, 1997; Stothard & Hulme, 1992). On the other hand, Miller and Smith (1990) noted that good readers performed better whilst reading, average readers showed an advantage for listening over reading, and poor readers performed similarly in both presentation modalities.

Edmonds and Pring (2006) compared the reading comprehension of children with VI and sighted children in producing inferences, while listening and reading aloud stories. They controlled for reading comprehension skill and matched children according to word reading and general reading skills. The results indicated that the advanced comprehenders were more successful in generating inferences compared to less advantaged comprehenders, supporting well established research findings with sighted participants (Cain & Oakhill, 1999; Oakhill, 1984; Yuill & Oakhill, 1991). With regards to modality, the sighted and children with VI were comparable on the reading task, but differed on the listening comprehension task. Specifically, in the listening comprehension test, the children with VI showed better performance in the literal questions compared to the inference generation ones.

Based on the above findings, we believe that it is a more complete approach to study reading and listening comprehension at the same time point and using the same materials during both modalities so a comparison can be feasible. As Edmonds and Pring (2006) noted, they could not directly compare the reading and listening modalities due to the use of different materials in the two phases of their study which were designed at different time points. Furthermore, the materials were not designed specifically to assess literal and inferential skills.

The present paper aims to contribute to the literature by investigating whether differences in the comprehender profile exist between Greek children with VI and sighted children. For this purpose, we use regression techniques to compare inference comprehension skills across the two types of children and assess their determinants. To enhance our understanding of modality effects on comprehension, we compare performance differentials pertaining to written and aural presentation of the tasks.

Our paper contributes to the literature in two ways. First, we use a non-parametric bootstrap augmented technique to unconditionally test differences in the inference generating process of the two types of children. Second, we use regression techniques to control for key characteristics such as age, sex, decoding skills and modality.

Based on the findings of Edmonds and Pring (2006) we expected that children with VI will show an advantage for literal questions under auditory information and that children with VI and sighted children will be comparable in their ability to generate inferences.

2. Methods

2.1 Participants

Our initial sample comprised of 43 children, 16 children with VI [1] and 27 sighted, attending two Greek public schools. All children with VI in our sample had visual acuities of less than 20/200 (=0.1) in the better eye with the best glass correction; hence classified as *legally blind*. An individual that is just-classified as *legally blind* is considered to be with *severe visual impairment* according to the World Health Organisation (WHO), whereas a *blind* individual is someone with visual acuities below 20/1000 (=0.02). The schools for both the children with VI and the sighted children follow the regular curricula; the only difference being that the children with VI use the Braille tactile system as their medium. All participants were native speakers of the Greek language without any behavioral, emotional or mental impairment. The study was approved by the Psychology Department Ethics Committee of Lancaster University. Written consent was obtained from the head teachers of the respective schools before the recruitment. Additionally, oral assent was obtained from each child before each task. The data were treated

[1] Eight children were congenitally blind and eight were early blind.

confidentially and all children were assigned an anonymization code that was used on their response sheets and coded on the data files.

Table 1 presents key descriptive statistics for the participants. Compared to the sighted participants attending Grades 1-6, the children with VI were about three years older.[2] In line with relevant literature, this occurred because in general children with VI show a developmental delay in their reading ability compared to sighted children (Dodd & Conn, 2000; Nolan & Kederis, 1969), which is in part related to the lengthy medical treatments that they undertake for their VI. In terms of decoding skills, the children with VI were about nine percentage points better at decoding nonwords, while the two groups were of similar decoding performance in real words. Males seem to be slightly underrepresented at about 37% of the sample.

[Insert Table 1 here]

2.2 Materials

2.2.1 Group Selection

All participants were assessed in their reading decoding skills using Exercises 1 (*nonwords*) and 2 (*real words*) of the Test-A (Padeliadu & Antoniou, 2008). For the children with VI the reading assessments were printed onto A4 sized papers in Braille. Exercises 1 and 2 contained 24 and 53 isolated nonwords and real words respectively, which were arranged in single columns on separate A4 papers. For the sighted children, the same words were used and presented in a similar, yet non-Braille way. The length of the nonwords ranged between two to

[2] We opt to compare sighted and children with VI on the basis of an elementary school's curriculum; thus, limit any heterogeneity from mixing with sighted participants of the next tier of school, i.e., a junior high school.

six syllables forming possible words in Greek. For the real words, the length was between two to eight syllables. All the words were presented in ascending difficulty.

The participant read aloud the items one by one. For each item, a binary response coding took the value zero (0) if the pronunciation was inappropriate and/or the use of lexical stress was inaccurate. A value of one (1) denoted that the participant had pronounced the word accurately and with a correct use of stress. The participant had three seconds to read each item before the item could be skipped. Administration of the task was discontinued when the participant made mistakes on five consecutive items.

2.2.2 Comprehension stories

Reading and auditory comprehension were assessed with a total of 7 stories, written in a suitable vocabulary for this age group. An example story is shown in Figure 1.

[Insert Figure 1 here]

The stories were divided into two lists; one list was read by the participants to assess reading comprehension, and another was read out to them by the researcher to assess listening comprehension. Each list consisted of three stories: List 1 included stories 1, 3, and 4; List 2 included stories 2, 5, and 7. A random selection of half of the participants in each group read the first list of stories and listened to the second list and the other half read the second list and presented the first one in an auditory modality. Six of the stories were used in Currie and Cain (2015) and one was adapted from Bishop and Adams (1992) as well as Cain, Oakhill, and Bryant (2004). The stories were forward- and back-translated in Greek by a Greek-English bilingual speaker and edited by a Greek primary school teacher and a Greek philologist. The average length of the stories was 156 words (range: 132 – 188).

Each text included three types of 12 questions; four literal information questions, four local cohesion questions and four global coherence questions. Examples of these questions can be seen in Figure 1. Answers with literal information, explicitly stated in the story, were required for the four literal content questions. The four local cohesion questions needed connections to be established between different sentences, within the context. General knowledge had to be connected with information stated explicitly in the text to answer the remaining four global coherence questions. The stories were printed onto separate A4 sheets in Braille for the children with VI and in text for the sighted children, using a normal size type font (Arial 12 pt.).

2.2.3 Procedure

The procedure was similar to Edmonds and Pring (2006). The children were tested individually in a quiet room setting, in one session that lasted 40 minutes on average for each child. The experimenter informed the children that they would be asked questions after each story and they would not be able to consult the text when answering. After reading aloud the nonword decoding task and the real word decoding task the children were administered three stories, one by one, to read out loud. Following each story, the texts were removed from the children, without the option of having the text present, and the children were asked by the researcher 12 questions about the story. The questions maintained the order in which the information occurred in the text and were not randomised. Children were given 10 sec to answer and if they did not answer, the experimenter repeated the question and another 10 sec were provided. The experimenter had a response sheet for each story, on which each participant's responses were noted. If a response was not given in this time the experimenter continued to the next question. In general, the children with VI were slower in reading the text aloud, due to their tactile reading modality, compared to their sighted counterparts, replicating previous research findings (e.g., Wetzel &

Knowlton, 2000). Following the reading aloud by the children, the experimenter informed them that three stories would be presented aloud, with questions being asked after each one about what happened in the story. This order of firstly reading aloud and then presenting the text aurally replicated the order followed by Edmonds and Pring (2006); however, during the same session for our study. After the end of the session the researcher thanked the child for their participation. All children participated enthusiastically.

2.2.4 Measures of text readability

To compute the readability scores of each text we used the Flesch Reading Ease Score (Flesch, 1948) adapted to the Greek language by Gagatsis (1985).[3] Recent studies stated that the Flesch Reading Ease measure (Flesch, 1948) is in general the most appropriate to use (Barbic et al., 2015; Didegah & Thelwall, 2013; Zhou, Green, & Jeong, 2016). The Flesch index was also considered suitable due to its compatibility with Greek texts. The original formula is the following:

$$\begin{aligned} &\mathit{Flesch\ Reading\ Ease\ Score} \\ &\quad = 206.835 - (1.015 \times \mathit{total\ word\ number} \\ &\quad /\mathit{total\ sentence\ number}) - (84.6 \times \mathit{total\ syllable\ number} \\ &\quad /\ \mathit{total\ word\ number}) \end{aligned}$$

Gagatsis (1985) stated that since the Greek words are longer on average compared to English and French, the coefficient 84.6 of the average word syllables should be replaced with 59.

[3] We have also considered the Gunning-Fog index (Gunning, 1968) and the LIX index (Anderson, 1983; Bjornsson, 1968). However, there was a good correspondence across measures, especially the LIX index which measures readability across several languages, such as Swedish, French, English, German and Greek (Lewis, Parker, Pound, & Sutcliffe, 1986).

$$Greek\ Flesch\ Reading\ Ease\ Score$$
$$= 206.835 - (1.015 \times total\,word\ number/total\ sentence\ number) - (59 \times total\ syllable\ number\,/\ total\,word\ number)$$

The scores range from 0-100, where 100 is very easy and 0 very hard.[4]

We report descriptive statistics of the Flesch Reading Ease Scores of each text in Table 2.

[Insert Table 2 here]

2.2.5 Econometric Analysis

We assume a panel model for the reading comprehension with random effects. The model may be expressed as:

$$y_{it} = a + \beta' \mathbf{X}_{it} + \nu_{it}$$
$$\nu_{it} = u_i + \varepsilon_{it}$$

where $\mathbf{X}_{it}$ is an $N \times T$ matrix of explanatory variables, ν_{it} is the composite error term that includes a random individual effect (u_i) and the usual regression random error (ε_{it}). Assumptions for the regression random error are of course well known. The properties of the random effects model are, however, appropriate in our setting due to the random individual effect (u_i) that allows only for correlation on the same participant (i) across different points in time(t) (i.e., tests), which is after all a realistic assumption. In a sense, the existence of a random individual effect ascertains that the scores of a participant (i) are not independent for observed or latent reasons. In a correctly specified model, the included explanatory variables should reduce the explanatory power of the (u_i) component, hence $corr(u_i, \mathbf{X}_{it}) = 0$. In such conditions, the

[4] The Greek adaptation of the Flesch Reading Ease Scale by Eustathiadis et al. (2002) classifies texts as "very easy" (100-90), "easy" (90-80), "moderately easy" (80-70), "medium" (70-60), "moderately hard" (60-50), "hard" (50-30) and "very hard" (30-0).

random effects estimator would be consistent and efficient.[5] A Hausman (1978) test can be used to assess the suitability of the random effects estimator, and therefore the appropriateness of the $corr(u_i, \mathbf{X}_{it}) = 0$ assumption.

3. Results

Small sample sizes are typical in visual impairment studies that might however induce certain biases. To overcome this difficulty and allow for potential differences in higher dimensions (e.g., skewness) between participants with VI and sighted ones to reveal themselves, we use the following bootstrapping method. We re-sample with replacement from the pools of sighted and participants with VI at the same proportion as in the original sample (i.e., 162/96). For our bootstrapping exercise we have used 60,000 replications. For further details on bootstrapping we direct you to Efron and Tibshirani (1993) who provide a detailed description of the technique.

Table 3 summarizes the performance of sighted and children with VI for the literal, global and local type of questions respectively under read and listen modalities. All of the participants were assessed on a set of six tests. Each of the three question sections comprised four sub-questions where a participant's answer can be either true or false. Hence the score for each of the question sections is in the 0-4 interval.

Inspection of Table 3 results suggests that the children with VI significantly outperform the sighted participants in the literal and local type of questions under the read modality only, $t(127) = 4.144$, $p < .001$ and $t(127) = 1.878$, $p = .064$. There is no significant difference in the global type of questions under read $t(127) = 0.385$, $p = .701$ or listen modalities $t(125) =$

[5] Strictly speaking in large samples the random effects and the fixed effects estimators are both consistent under the $corr(u_i, \mathbf{X}_{it}) = 0$ assumption, however the random effects is efficient.

1.053, p = .295. The bootstrapped version of the t-test is based on Desagné, Castilloux, and Angers (1997), which has also been used in Colleagues and Author (2014) among others.

[Insert Table 3 here]

In our study, we measure knowledge and skill using real words and pseudo words. Nevertheless, the fact that either of these measures are not perfectly correlated means that one cannot be used as a substitute to the other.[6] In other words, using an age-matched sample analysis would imply that all skill and knowledge variation has been captured, which is not the case. Our analysis controls for age, skill and knowledge differences at the same time through the regression framework.

Table 4 presents the regression results for the reading comprehension measures. Columns I-IV present the results for the literal type of questions, while the global and local types are presented in columns V-IX and IX-XII respectively. Columns XIII-XVI present the overall score regression results. In presenting the results for each of the measures we start from a basic formulation that contains only the visually impaired dummy (VI) and progress to extended formulations that control for an increasing number of factors. In particular, the explanatory variables included are: age, sex (male), Flesch and reading ability. Real and Pseudo are included in models II and III, with the former utilizing the percentage of real words and the latter the percentage of pseudo words, as proxies for reading ability. Model IV includes both reading ability proxies and further controls for modality. Text fixed effects (Text FE) are included to capture any further unobserved differences between the texts. All model inferences are based on

[6] For example, a Spearman rank correlation for Real Words (%) with Age is at 0.554 and for Pseudo Words (%) with Age is at 0.589.

Huber-White standard errors that are robust to within-cluster correlations to pupil performance with the cluster defined at the child level.

In Table 4, Model XVI shows that the estimated coefficient on the visually impaired is statistically significant with a positive sign ($\widehat{b}$ = 0.982, z = 1.918) after controlling for age, sex, Flesch, reading ability and modality and is suggestive of the higher performance in reading comprehension for the Braille readers. The pattern does not reach conventional significance levels for two of the three sub-categories of the questions, namely the global ($\widehat{b}$ = 0.251, z = 1.357) and the local ($\hat{b}$ = 0.132, z = 0.571). Hence, the overall score results seem to be driven mostly by the literal type, which has the highest adjusted r-squared ($\bar{R}^2 = 25.16$). This finding is in line with the unconditional results from the earlier section where the children with VI were significantly better in the literal type of questions.

The modality variable suggests that superior text comprehension is not consistently achieved through reading or listening; instead the relative importance of the reading and the auditory channel of receiving information changes with regards to the type of question. In particular, the positive and statistically significant coefficient of the modality variable ($\widehat{b}$ = 0.306, z = 2.508) in the models related to the literal questions suggests that visually or tactilely reading the text is associated with higher performance. By contrast, a negative and statistically significant coefficient on the modality variable ($\widehat{b}$ = -0.188, z = 1.678) in the models pertaining to the local questions suggests that higher performance in these questions is achieved under an auditorial presentation of the text material.

Flesch is statistically significant for local questions with a positive coefficient ($\hat{b}$ = 0.106, z = 5.047). For global and literal questions (Models IV and VIII respectively) Flesch is significant with a negative sign ($\widehat{b}$ = -0.060, z = 3.333) and ($\widehat{b}$ = -0.088, z = 4.631) respectively.

The percentage of real and pseudo words capture reading ability, which show a positive correlation with age $r = 0.468$, $p < .001$ and $r = 0.599$, $p < .001$, respectively. These two variables do not capture the same effects as can be evidenced by the fact that the models containing both variables have better adjusted R-squared values from the models containing either of these. The fact that age is not statistically significant is not counterintuitive as it may be plausibly explained by the knowledge and knowhow that children have accumulated over the years, which is captured by the real and pseudo words respectively.

[Insert Table 4 here]

3.1 Further investigation on visual impairment categories

In this part of the analysis we split our sample of children with VI in two sub-groups, namely those with severe VI and those that are blind and repeat the analysis for each group.[7] The variable *Severe VI* takes the value 1 for children with severe VI, zero otherwise. The variable *Blind* takes the value 1 for children with blindness, zero otherwise. We also form two sub-groups based on whether the child was congenitally blind (born blind or lost vision in infancy) or whether this condition came later in life and repeat the analysis for each group. The variable *Birth VI* takes the value 1 for children that were congenitally blind, zero otherwise. The variable *Early VI* takes the value 1 for children that severe VI (or blindness) appeared post-birth, zero otherwise. Similar to the main analysis, a positive and statistically significant coefficient on *Severe VI*, *Blind*, *Birth VI* and *Early VI* would suggest that the respective group's reading comprehension is superior to the sighted control group. Table 5 presents the results of this

[7] All participants and in all cases of our study tactilely read the material in Braille.

analysis, with Models 2-5 referring to the categories of *Severe VI*, *Blind*, *Birth VI* and *Early VI respectively*, and Model 1 repeating Model XVI of the main analysis for comparison purposes.[8]

[Insert Table 5 here]

With respect to the severe VI/blind split our results suggest that the children with blindness are significantly better in text comprehension compared to their sighted peers, as evidenced by the positive and statistically significant coefficient ($\hat{b} = 1.078, z = 1.974$). By contrast, no significant difference in reading comprehension is verified between children with severe VI and the sighted control group ($\hat{b} = 0.300, z = 0.583$).

With regards to the birth/non-birth split, the analysis reveals that the superior performance of the children with VI documented in the main part of the paper, is primarily driven by the children that were congenitally blind. This is corroborated by the positive and significant coefficient ($\hat{b} = 1.636, z = 4.238$).

3.2 Robustness tests

A series of robustness checks has been performed to ensure the statistical validity of our results. As an alternative to regression (Stuart, 2010), the *k*-means nearest-neighbour matching method has been implemented.[9] The main conclusion that the children with VI show superior performance in the literal type of questions ($\hat{b}$ = 0.370, z = 2.990) is also verified under this

[8] We present the analysis for the Overall Score for brevity and a similar pattern is observed for all other measures.

[9] The *k*-means nearest neighbor is a non-linear, non-parametric technique that matches together participants with similar characteristics and has been used extensively in the fields of economics (Almond, Chay, & Lee, 2005), finance (Olson & Zoubi, 2008) and textual analysis (Jiang, Pang, Wu, & Kuang, 2012).

analysis. The second of the robustness checks relaxes the assumption of the test score being a continuous variable by applying a panel ordered logit model with random effects. The method has been used extensively, see for example Hedeker and Gibbons (1994); Greene and Hensher (2009) and references therein. A brief inspection verifies that the visually impaired perform significantly better than the control group at the overall score ($\hat{b}$ = 1.198, z = 1.848), and this is mainly driven by their performance in the literal type of questions ($\hat{b}$ = 1.654, z = 3.097). The third robustness check dispenses with the panel dimension assumption by pooling the results across the tests for every child. These results confirm that children with VI show a better reading comprehension profile, particularly in the literal questions ($\hat{b}$ = 1.731, z = 2.847).[10] Overall, all robustness checks corroborate the results of our main analysis.

4. Discussion

The present study contributes to the literature by investigating differences in the comprehender profile of Greek children with VI and sighted children. Additionally, we aimed to enhance our understanding on the effect of written and aural presentation on the children's reading comprehension.

Perhaps the study closest to ours is the study of Edmonds and Pring (2006) that finds that children with VI show a better reader comprehender profile with regards to the literal type of questions under auditory presentation of the material. This is in line with the literature on superior memory performance of participants with VI (Pring, 2008) as well as claims on the lower memory load of literal questions (Edmonds & Pring, 2006). With regards to the working

[10] All tabulated results pertaining to the robustness checks are omitted for brevity and are available from the authors upon request.

memory, a recent study of Withagen, Kappers, Vervloed, Knoors, and Verhoeven (2013) finds that children with VI outperform their sighted counterparts at working memory tasks and short-term memory tasks. Our study generalises this finding by providing evidence that children with VI show an overall better reader comprehender profile under auditory or reading presentation of the information. We elaborate on this finding below.

Some of the differences we obtain, particularly with regards to the better comprehender profile that Greek children with VI show, may be attributed to three reasons. First, the findings of Edmonds and Pring (2006) may have been driven by the fact that the English language in not as alphabetically transparent and with relatively easy syllabic structure as is the case with the Greek language. Phonological awareness and alphabetic decoding skills of children in transparent orthographies have been found to be acquired faster compared to those of English-speaking children (Ziegler & Goswami, 2005).

Second, and in contrast to the English braille, the Greek braille does not have any abbreviations or contractions and requires most words to be entirely spelled (Argyropoulos & Martos, 2006). Greek braille readers would be simply reading what they see; thus putting less effort to recall abbreviations and contractions. Hence, the Greek braille readers may be better suited to concentrate on comprehension monitoring rather than accuracy of word reading (Yuill & Oakhill, 1991). As noted in Veispak et al. (2012) and Argyropoulos and Papadimitriou (2015) the children with VI seem to adopt an effective decoding mechanism early in their school years and rely upon it. Thus, they may be in a position to understand the text better, which would subsequently help them to answer the questions. This may explain why Edmonds and Pring (2006) only find superior performance of children with VI under the auditory presentation of information.

Third, the relation between working memory and reading comprehension is well established in recent studies (e.g., Cain, Oakhill, & Bryant, 2004; Yuill & Oakhill, 1991). Since, people with VI may rely more on their memory and attentional focus due to their lack of vision, one might hypothesize that better reading and listening comprehension may be a result of enhanced attentional and working memory capacities. Given that recent studies (e.g., Cattaneo & Vecchi, 2011; Withagen et al., 2013) report better performance by individuals with VI compared to their sighted counterparts in short-term and working memory tasks, it could be expected that participants with VI provide more answering from memory. Research shows that individuals with VI outperform their sighted cohorts in short-term and working memory tasks (Cattaneo & Vecchi, 2011; Withagen et al., 2013). In line with the above hypothesis, Pigeon and Marin-Lamellet (2015) found that early blind adult participants performed better in selective, sustained and divided attention tasks and working memory tasks compared to their sighted counterparts. Additionally, Argyropoulos et al. (2017) show that reading comprehension and overall reading ability is significantly correlated with the verbal working memory performance of children with VI and teenagers.

The fact that inference making is a core aspect of reading comprehension and based on recent studies where individuals' skills with VI in working memory tasks are found enhanced (see Argyropoulos et al., 2017), we can assume that working memory may play a role in their superior performance in literal questions when reading Braille. More specifically, the children's with VI better reading comprehension performance in the literal questions, primarily based on memory, can be explained on the assumption that children with VI might be more enhanced in their working memory skills due to the development of their memory skills and tactile tactics in order to compensate for their sight absence. More specifically, it has been noted that touch is an intersensory process leading to a cognitive outcome through tactile perception (Millar, 1997).

Based on our further analysis between congenitally and early blind children, we observed that the better performance in reading comprehension of the children with VI is primarily driven by the children that were congenitally blind. Our results match those found in the literature, where congenitally blind children outperformed their sighted counterparts with regards to working memory tasks (Hull & Masson, 1995). By contrast, children classified as adventitiously blind showed comparable performance to their sighted counterparts (Hull & Masson, 1995). This difference between congenitally and adventitiously blind children may be plausibly attributed to the different cognitive strategies used, which could result in a differentiated performance with regards to their sighted controls (Cattaneo et al., 2008). Our finding is, in part, explained by the fact that working memory is a strong predictor of reading comprehension, with congenitally blind consistently outperforming their sighted cohorts in working memory (Pham & Hasson, 2014). Individuals with visual impairments from birth may be most likely to show changes in brain function originating from their blindness (Wan, Wood, Reutens, & Wilson, 2010).

One other interesting finding of our study is that both groups of children benefit from reading the text when they need to answer literal type of questions, while the auditory channel is beneficial when local type of questions are to be answered. By contrast, global type of questions do not seem to be affected by modality. In the study of Edmonds and Pring (2006), the modality effect may not be directly assessed, as different materials were used for the study when reading and listening to the stories, which took place at different time points. A plausible explanation for the differences observed between the two modalities in the present study is that the children might differ in the strategies used for their comprehension monitoring during story reading. It seems that the modality does not affect the performance in the inferential questions, since the difference in local questions is marginal. By contrast, there is a bigger focus placed on reading comprehension, describing and summarising the text after years 1 and 2 at school, and in this way the children are trained in answering literal questions, stated explicitly in the text. This gradual increase in the emphasis of reading and link with comprehension with subsequent connection to the efficiency and effectiveness of children's decoding of information has been highlighted in the study of Diakidoy, Styllianou, Karefillidou, and Papageorgiou (2005). Also, even in a quiet room, the children might lose their concentration when listening compared to reading a text. Besides, it seems that there is a positive relation between length of text and processing load required by the listeners as highlighted in Osada (2004) and Thomson and Rubin (1996).

We used the Greek Flesch readability score index to assess the difficulty of each text used. Flesch is found statistically significant and with a positive sign for the local type of questions as expected given that the Flesch index is specifically attuned to capture this. By contrast, Flesch is not significant in line with our prior assumptions for global questions since answering these questions is not necessarily related to the text complexity. For literal type of questions, a negative sign indicates that the Flesch index is, perhaps, not able to capture these questions; hence a better proxy may be desirable to sufficiently capture all aspects of reading difficulty (Hartley, 2016).

The above findings could have important policy implications as they could be used as a basis for justifying the costs of making and printing books and notes in Braille. Adequate access to materials in a range of formats is needed for children with VI to develop their literacy skills. Traditional methods by studying through Braille or large print may be time-consuming, demanding on resources, and hence limit access to existing information (Argyropoulos et al., 2017). Recent technological advancements, such as software and/or portable devices quickly converting texts to Braille could increase the access to information, without restricting people with VI on the method of delivery of information (e.g., haptic and/or auditory).[11] Ultimately such advancements could enhance the integration of people with VI in the society.

The reading skills used, proxied by real and pseudo-word tests, would be correlated to a vocabulary effect. We would have opted for a standardized Greek receptive and/or expressive vocabulary test, however and to the best of our knowledge one does not exist for children with visual impairments. We are mindful of the Morash and McKerracher (2017) critique on utilizing a standardized vocabulary test for sighted population upon a population with visual impairments for the English language. The fact that vocabulary has been shown to be a strong predictor of reading comprehension (Muter, Hulme, Snowling, & Stevenson, 2004) and inference making (Oakhill & Cain, 2012) from elementary grades (Ouellette & Beers, 2010) to early adulthood (Braze, Tabor, Shankweiler, & Mencl, 2007) warrants research interest. We leave the issue of a standardized vocabulary measure for children with visual impairments as well as the possible link between working memory and inference making for children with visual impairments as directions to future research.

[11] For example, BRAILLI ltd, a novel company that produces handheld smart devices that turn any text into braille code, enhancing the integration of children/adults with visual impairment with technology and society. For more info see here: https://www.kent.ac.uk/enterprise/hub/news/articles/articles/2016bigideasshortlist.html

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References

Ackerman, B. P. (1986). Referential and causal coherence in the story comprehension of children and adults. *Journal of Experimental Child Psychology, 41,* 336-366.

Almond, D., Chay, K.Y., & Lee, D. S. (2005). The costs of low birth weight. *Quarterly Journal of Economics, 120*, 1031-1083.

Anderson, J. (1983). Lix and rix: Variations of a littleknown readability index. *Journal of Reading, 26*(6), 490– 496.

Argyropoulos, V., & Martos, A. C. (2006). Braille literacy skills: an analysis of the concept of spelling. *Journal of Visual Impairment & Blindness, 100,* 676-686.

Argyropoulos, V., & Papadimitriou, V. (2015). Braille reading accuracy of students who are visually impaired: the effects of gender, age at vision loss, and level of education. *Journal of Visual Impairment & Blindness, 109*(2), 107-118.

Argyropoulos, V., & Papadimitriou, V. (2017). Spelling accuracy and students with visual impairments: A quantitative and qualitative approach of spelling errors. *International Journal of Educational Research*, *83*, 135–141.

Argyropoulos, V., Masoura, E., Tsiakali, T. K., Nikolaraizi, M., & Lappa, C. (2017). Verbal working memory and reading abilities among students with visual impairment. *Research in Developmental Disabilities*, *64*, 87-95.

Barbic, S. P., Roberts, K., Durisko, Z., Lee, C., Yachouh, R., Guriel, J., & McKenzie, K. (2015). Readability assessment of psychiatry journals. *European Science Editing, 41*(1), 3–10.

Bishop, D. V. M., & Adams, C. (1992). Comprehension problems in children with specific language impairment: Literal and inferential meaning. *Journal of Speech and Hearing Research*, *35,* 119 –129.

Bowyer-Crane, C., & Snowling, M. J. (2005). Assessing children's inference generation: what do tests of reading comprehension measure? *British Journal of Educational Psychology, 75,* 189–201.

Braze, D., Tabor, W., Shankweiler, D. P., & Mencl, W. E. (2007). Speaking up for vocabulary: Reading skill differences in young adults. *Journal of Learning Disabilities, 40,* 226–244.

Cain, K., & Oakhill, J. V. (1999). Inference making and its relation to comprehension failure. *Reading & Writing, 11,* 489-503.

Cain, K., & Oakhill, J. (2014). Reading comprehension and vocabulary: Is vocabulary more important for some aspects of comprehension? *L'Année Psychologique, 114,* 647-662.

Cain, K., Oakhill, J. V., Barnes, M. A., & Bryant, P. E. (2001). Comprehension skill, inference making ability, and the relation to knowledge. *Memory and Cognition, 29,* 850–859.

Cain, K., Oakhill, J., & Bryant, P. E. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96,* 31–42.

Casteel, M. A. (1993). Effects of inference necessity and reading goal on children's inference generation. *Developmental Psychology, 29,* 346-357.

Casteel, M. A., & Simpson, G. B. (1991). Textual coherence and the development of inferential generation skills. *Journal of Research in Reading, 14,* 116-129.

Cattaneo, Z., & Vecchi, T. (2011). Blindness and sensory compensation. In Z. Cattaneo, & T. Vecchi (Eds.), *Blind vision* (pp. 11–48). Cambridge, MA: MIT Press.

Cattaneo, Z., Vecchi, T., Cornoldi, C., Mammarella, I., Bonino, D., Ricciardi, E., & Pietrini, P. (2008). Imagery and spatial processes in blindness and visual impairment. *Neuroscience & Biobehavioral Reviews, 32*, 1346–1360.

Colleagues and Author. (2014).

Currie, N., & Cain, K. (2015). Children's inference generation: The role of vocabulary and working memory. *Journal of Experimental Child Psychology 137*, 57–75.

Curtis, M. (1980). Development of components of reading skill. *Journal of Educational Psychology, 72,* 656–669.

Desagne, A., Castilloux, A-M., & Angers, J-F. (1998). The use of the bootstrap statistical method for the pharmacoeconomic cost analysis of skewed data. *Pharmaco Economics, 13,* 487-497.

Diakidoy, I. A., Styllianou, P., Karefillidou, C., & Papageorgiou, P. (2005). The relationship between listening and reading comprehension of different types of tests at increasing grade levels. *Reading Psychology, 26,* 55–80.

Didegah, F., & Thelwall, M. (2013). Which factors help authors produce the highest impact research? Collaboration, journal and document properties? *Journal of Informetrics, 7*(4), 861–873.

Dodd, B., & Conn, L. (2000). The effect of braille orthography on blind children's phonological awareness. *Journal of Research in Reading, 23,* 1–11.

Edmonds, C. J. & Pring, L. (2006). Drawing inferences from written and spoken language: a comparison of children with visual impairment and children with sight. *British Journal of Developmental Psychology, 24*(2), 337–52.

Efron, B., & Tibshirani, R. J. (1994). *An introduction to the bootstrap*. CRC press.

Eustathiadis, S., Antonopoulou, N., Zourou, K., Triantafullidis, T. (2002). Reading software for Greek texts. Retrieved from http://www.greeklanguage.gr/greekLang/modern_greek/foreign/tools/readability/01.html

Flesch, R. F. (1948). A new readability yardstick. *Journal of Applied Psychology, 32,* 221-233.

Gagatsis, A. (1985). Oral formulation of Mathematical Formulae. *Educational Review, 3,* 21-46 (in Greek).

Garnham, A., & Oakhill, J. V. (1996). The mental models theory of language comprehension. In B. K. Britton & A. C. Graesser (Eds.), *Models of understanding text* (pp. 313-339). Hilsdale, NJ: Erlbaum.

Graesser, A. C., & Clark, L. F. (1985). *Structures and procedures of implicit knowledge*. Norwood, NJ: Ablex.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension, *Psychological Review, 101*, 371–395.

Greene, H. W., & Heshner, A. D. (2009). Modeling Ordered Choices. Cambridge, UK: Cambridge University Press.

Gunning, R. (1968). The Fog index after twenty years. *Journal of Business Communications, 6,* 3-13.

Hartley, J. (2016). Is time up for the Flesch measure of reading ease? *Scientometrics, 107*(3), 1523–1526.

Hausman, J. A. (1978). Specification Tests in Econometrics. *Econometrica, 46,* 1251–1271.

Hedeker, D., & Gibbons, R. D. (1994). A random-effects ordinal regression model for multilevel data. *Biometrics, 50,* 933-944.

Hoover, W., & Gough, P. (1990). The simple view of reading. *Reading and Writing,* 2(2), 127–160.

Hull, T., & Mason, H. (1995). Performance of blind children on digit-span tests. *Journal of Visual Impairment & Blindness, 89,* 166-169.

Jiang, S., Pang, G., Wu, M., & Kuang, L. (2012) An improved k-nearest-neighbor algorithm for text categorization. *Expert Systems with Applications, 39*(1), 1503-1509.

Johnson-Laird, P. N. (1983) *Mental models: towards a cognitive science of language, inference, and consciousness*. Cambridge, UK: Cambridge University Press.

Kendeou, P., van den Broek, P., Helder, A., & Karlsson, J. (2014). A cognitive model of reading comprehension: Implications for reading difficulties. *Learning Disabilities Research and Practice*, 29, 10–16.

Kendeou P., van den Broek P., White M. J., Lynch J. S. (2009). Predicting reading comprehension in early elementary school: The independent contributions of oral language and decoding skills. *Journal of Educational Psychology, 101*, 765–778.

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction integration model. *Psychological Review, 95*, 163–182.

Kintsch, W., & Kintsch, E. (2005). Comprehension. In S. G. Paris & S. A. Stahl (Eds.), *Children's reading comprehension and assessment* (pp. 71–92). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lewis, N. R., Parker, L. D., Pound, G. D., & Sutcliffe, P. (1986). Accounting report readability: The use of readability techniques. *Accounting and Business Research, 16,* 199-213.

Long, D. L., & Chong, J. L. (2001). Comprehension skill and global coherence: A paradoxical picture of poor comprehenders' abilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 1424–1429.

Lynch, J. S., Van den Broek, P., Kremer, K., Kendeou, P., White, M. J. and Lorch, E. P. (2008). The development of narrative comprehension and its relation to other early reading skills. *Reading Psychology, 29*, 327–365.

Millar, S. (1997). *Reading by touch*. London: Routledge.

Miller, S. D., & Smith, D. E. P. (1990). Relations among oral reading, silent reading and listening comprehension of students at differing competency levels. *Reading Research and Instruction, 29,* 73-84.

Morash, V. S., & McKerracher, A. (2017). Low reliability of sighted-normed verbal assessment scores when administered to children with visual impairments. *Psychological Assessment, 29*(3), 343-348.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundation of early reading development: Evidence from a longitudinal study. *Developmental Psychology, 40,* 665– 681.

Nation, K., Clarke, P., Marshall, C. M., & Durand, M. (2004). Hidden language impairments in children: Parallels between poor reading comprehension and specific language impairments? *Journal of Speech, Language, and Hearing Research, 47*, 199–211.

Nation, K., & Snowling, M. (1997). Assessing reading difficulties: The validity and utility of current measures of reading skill. *British Journal of Educational Psychology, 67,* 359–370

Nolan, C., & Kederis, C. (1969). *Perceptual factors in Braille word recognition*. New York: American Foundation for the Blind.

Oakhill, J. V. (1982). Constructive processes in skilled and less-skilled comprehenders' memory for sentences. *British Journal of Psychology, 73,* 13-20.

Oakhill, J. V. (1984). Inferential and memory skills in children's comprehension of stories. *British Journal of Educational Psychology, 54,* 31-39.

Oakhill, J. V., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading*, 16, 91–121.

Osada, N. (2004). Listening comprehension research: a brief review of the past thirty years. *Dialogue, 3,* 53-66.

Ouellette, G., & Beers, A. (2010). A not-so-simple view of reading: How oral vocabulary and visual-word recognition complicate the story. *Reading and Writing, 23,* 189–208.

Padeliadu, S., & Antoniou, F. (2008). *Reading Test (Test-A)*. Program EPEAEK- Greek Ministry of Education.

Papadimitriou, V., & Argyropoulos, V. (2017). The effect of hand movements on braille reading accuracy. *International Journal of Educational Research, 85*, 43–50.

Perfetti, C. A., Stafura, J. Z., & Adlof, S. M. (2013). Reading comprehension and reading comprehension problems: a word-to-text integration perspective. In B. Miller, L. E. Cutting & P. McCardle (Eds.), *Unravelling reading comprehension: behavioral, neurobiological, and genetic components* (pp. 22-32). Baltimore: Paul Brookes Publishing Co.

Perfetti, C., Yang, C. L., & Schmalhofer, F. (2008). Comprehension skill and word-to-text integration processes. *Applied Cognitive Psychology, 22,* 303–318.

Pham, A. V., & Hasson, R. M. (2014). Verbal and visuospatial working memory as predictors of children’s reading ability. *Archives of Clinical Neuropsychology, 29*(5), 467-477.

Pigeon, C., & Marin-Lamellet, C. (2015). Evaluation of the attentional capacities and working memory of early and late blind persons. *Acta psychologica, 155,* 1-7.

Pring, L. (2008). Psychological characteristics of children with visual impairments: learning, memory and imagery. *British Journal of Visual Impairment, 26*(2), 159-169.

Protopapas, A., Sideridis, G. D., Mouzaki, A., & Simos, P. G. (2007). The development of lexical mediation in the relationship between text comprehension and word reading skills in Greek. *Scientific Studies of Reading, 11,* 165–197.

Sticht, T. G., Beck, L. J., Hauke, R. N., Kleinman, G. M., James, J. H. (1974). *Auding and reading: A developmental model*. Alexandria, VA: Human Resources Research Organization.

Sticht, T. G., & James, J. H. (1984). Listening and reading. In Pearson, P.D. (Ed.), *Handbook of reading research* (pp. 293-317). New York: Longman.

Stothard, S., & Hulme, C. (1992). Reading comprehension difficulties in children. *Reading and Writing: An Interdisciplinary Journal, 4,* 245-256.

Stuart, E. A. (2010). Matching methods for causal inference: A review and a look forward. *Statistical science: a review journal of the Institute of Mathematical Statistics*, *25*(1), 1-21.

Thurlow, R., & van den Broek, P. (1997). Automaticity and inference generation. *Reading and Writing Quarterly, 13,* 165–184.

Trabasso, T., Secco, T., & van den Broek, P. (1984). Causal cohesion and story coherence. In H. Mandl, N. L. Stein, & T. Trabasso (Eds.), *Learning and comprehension of text*. Hillsdale, NJ: Erlbaum.

van den Broek, P. (1989). Causal reasoning and inference making in judging the importance of story statements. *Child Development, 60,* 286-297.

van den Broek, P. (1994). Comprehension and memory of narrative texts: Inferences and coherence. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 539-588). San Diego: Academic Press.

Veispak, A., Boets, B., & Ghesquiere, P. (2012). Parallel versus sequential processing in print and braille reading. *Research in Developmental Disabilities, 33*, 2153–2163.

Verhoeven, L., & van Leeuwe, J. (2008). Prediction of the development of reading comprehension: A longitudinal study. *Applied Cognitive Psychology, 22*, 407–423.

Wan, C. Y., Wood, A. G., Reutens, D. C., & Wilson, S. J. (2010). Early but not late-blindness leads to enhanced auditory perception. *Neuropsychologia, 48*, 344-348.

Wetzel, R., & Knowlton, M. (2000). A Comparison of Print and Braille Reading Rates on Three Reading Tasks. *Journal of Visual Impairment & Blindness, 94*(3).

Withagen, A., Kappers, A. M. L., Vervloed, M. P. J., Knoors, H., and Verhoeven, L. (2013). Short term memory and working memory in blind versus sighted children. *Research in Developmental Disabilities, 34*, 2161–2172.

Yuill, N. M., Oakhill, J. V., & Parkin, A. (1989). Working memory, comprehension ability and the resolution of text anomaly. *British Journal of Psychology, 80*, 351–361.

Yuill, N., & Oakhill, J. (1991). *Children's problems in text comprehension: An experimental investigation*. Cambridge, UK: Cambridge University Press.

Zhou, S., Green, P. A. & Jeong, H. (2016, in preparation). How consistent are the best-known readability equations in estimating the readability of design standards? (Copies available from pagreen@umich.edu).

Ziegler, J. C., & Goswami, U. C. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*, 3-29